

Exploring users inter-temporal preferences for measuring transport social equity effects

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ABSTRACT

It exists different ways for defining a welfare function. Traditionally, welfare economic theory foundation is based on the Net Present Value (NPV) calculation where the time dependent preferences of considered agents are taken into account. However, the time preferences, remains a controversial subject. Currently, the traditional approach employs a unique discount rate for various agents. Nevertheless, this way of discounting appears inconsistent with sustainable development. New research work suggests that the discount rate may not be a homogeneous value. The discount rates may change following the individual's preferences. A significant body of evidence suggests that people do not behave following a constant discount rate. In fact, UK Government has quickly recognized the power of the arguments for time-varying rates, as it has done in its official guidance to Ministries on the appraisal of investments and policies. Other authors deal with not just time preference but with uncertainty about future income (precautionary saving). In a situation in which economic growth rates are similar across time periods, the rationale for declining social optimal discount rates is driven by the preferences of the individuals in the economy, rather than expectations of growth. However, these approaches have been mainly focused on long-term policies where intergenerational risks may appear.

The traditional cost-benefit analysis (CBA) uses a unique discount rate derived from market interest rates or investment rates of return for discounting the costs and benefits of all social agents included in the CBA. However, recent literature showed that a more adequate measure of social benefit is possible by using different discount rates including inter-temporal preferences rate of users, private investment discount rate and inter-temporal preferences rate of government. Actually, the costs of opportunity may differ amongst individuals, firms, governments, or society in general, as do the returns on savings. In general, the firms or operators require an investment rate linked to the current return on savings, while the discount rate of consumers-users depends on their time preferences with respect of the current and the future consumption, as well as society can take into account the intergenerational well-being, adopting a lower discount rate for

today's generation. Time discount rate of social actors (users, operators, government and society) places a lower value in a future gain, but the uncertainty about future income strongly determines the individual preferences. These time and uncertainty depends on preferences and should be integrated into a transport policy formulation that may have significant social impacts. The discount rate of a user cannot be the same than the operator's discount rate. The preferences of both are different.

In addition, another school of thought suggests that people, such as a social group, may have different attitudes towards future costs and benefits. Particularly, the users have different discount rates related to their income. Some research work tried to modify user discount rates using a compensating weight which represents the inverse of household income level. The inter-temporal preferences are a proxy of the willingness to pay during the time. Its consideration is important in order to make acceptable or not a policy or investment.

1. INTRODUCTION AND BACKGROUND

It exists different ways for identifying transport policy benefits through a welfare function. Traditionally, welfare economic theory foundation is based on the Net Present Value (NPV) calculation where the time dependent preferences of considered agents are taken into account. However, time preferences remain a controversial subject. Currently, the traditional approach employs a unique discount rate for various agents. Nevertheless, this way of discounting appears inconsistent with sustainable development. New research work suggests that the discount rate may not be a homogeneous value (Guzman et al., 2013). The discount rates may change following the individual's preferences. Significant evidences suggest that people do not behave following a constant discount rate. In fact, UK Government has quickly recognized the power of the arguments for time-varying rates, as it has done in its official guidance to Ministries on the appraisal of investments and policies. Other authors deal with time preference and uncertainty about future income (precautionary saving). In a situation in which economic growth rates are similar across time periods, the rationale for declining social optimal discount rates is driven by the preferences of the individuals in the economy, rather than expectations of growth.

The traditional cost-benefit analysis (CBA) uses a unique discount rate derived from market interest rate for discounting the costs and benefits of all social agents included in the CBA. However, recent literature showed that a more adequate measure of social benefit is possible by using different discount rates including inter-temporal preferences rate of users, private investors discount rate and inter-temporal preferences rate of government (Guzmán, Di Ciommo & Hoz 2013). Actually, the cost of opportunity may differ amongst individuals, firms, governments, or society in general, as do the returns on savings. In general, the firms or operators require an investment rate linked to the current return on savings, while the discount rate of consumers-users depends on their time

preferences with respect of the current and the future consumption, as well as society can take into account the intergenerational well-being, adopting a lower discount rate for today's generation. Time discount rate of social actor (users, operators, government and society) places a lower value in a future gain. Time and uncertainty depends on preferences and should be integrated into a transport policy formulation that may have significant social impacts.

In addition, another school (Martens, 2011) of thought suggests that people, such as a social group, may have different attitudes towards future costs and benefits. Particularly, the users have different incomes that determine different inter-temporal preferences. Some research work tried to modify user discount rates using a compensating weight which represents the inverse of household income level (Wang et al. 2014). However this paper shows that even when a higher weight is given to low income users in a cost-benefits analysis and they are losing more in terms of time, the congestion pricing implementation seems to be a beneficial policy. Two different factors determine this result: 1) the generalized composite cost-benefit indicator is positive because of the highest gain of upper income people in terms of time saving, and 2) low income people seem to be more mechanized trips depending. Actually, mechanized trip dependency has rapidly increased for lower skilled and lower income people in European cities like London, Paris and Madrid. This is due to the simultaneous dispersal towards of both workers' home locations (in their search for more affordable housing) and their employment locations (due to the flight of jobs from city centers and the fragmentation of employment activities) (Monzón, de la Hoz 2009, Korsu, Wenglenski 2010). They can shift to public transport, but because of the mismatch of residential and work locations, when they are excluded by the car use, their gain in terms of time saving benefits by congestion pricing will be irrelevant because of the gain in terms of time for public transport with congestion pricing is negligible. The people who 'give up' the tolled highway have to change their mobility strategies; i.e. reduce their use of the tolled roads and find new arrangements for their trips (Di Ciommo, Lucas 2013). Recently the transport literature has considered not only the income affordability and the consequent re-distributional effects of road pricing schemes, but also time budget constraints and the issue of time poverty (Palma-Solís et al. 2009).

Two ex-post studies of the equity effects of the Stockholm Congestion Pricing Scheme have also re-calculated the expected welfare effects on commuters across income, gender, and initial commute mode using observed data on commute mode choice from a panel survey of households before and after the trial (Karlström, Franklin 2009). The results showed an irregular trend for changes in trip patterns, with the greatest burden of congestion pricing falling on the lowest and highest income groups. Work-hour flexibility was significantly associated with shifts to an earlier departure time, and this, in turn, was correlated with income. In other terms, higher income people showed a more flexible work schedule that allows them to more easily avoid the payment of the congestion toll (Karlström, Franklin 2009).

The literature shows that the time constraints are a crucial point for exploring the social equity effects related to the congestion pricing. This paper highlights that a new kind of policy analysis should be adopted for checking the social benefits of implemented policy: the compositeness of CBA leads to less transparent indicators. Each society is free to adopt the social paradigm it wishes, by giving a higher weight to a population group or to another. Therefore, a context sensitive indicators for transport planning and a measurement framework should be defined for achieving consistent, integrated and transparent indicators (Miller, Witlox & Tribby 2013). This paper will contribute to the definition of a measurement framework including consistent, disaggregated and transparent indicators.

2. METHODOLOGY

Urban agglomerations are complex systems. The behavior of each of its subsystems is a highly interrelated and complex task. Interactions between transportation, land-use, travel patterns and public policies have to be taken into consideration over long periods of time. This system can be termed dynamic because its interactions cause changes over time, and is useful in evaluating long-term scenarios where the behavior to be assessed is the consequence of complex interactions.

Here, we propose to use a model to assist stakeholders in transport planning decisions, e.g. the equity in a road charge scheme in the Madrid Region. Therefore, we used a system dynamics (SD) approach consists of linking subsystems of land-use and transport using an optimization procedure. The major qualitative SD methods are Causal Loop Diagrams (CLDs). CLDs are especially suitable for be used to challenge opposing assessments by way of counter-expertise and/or visualization of alternatives and to help to create a consensus view of a problem among different stakeholders (Pfaffenbichler 2011). The advantage of this SD approach is the possibility to disaggregate the cost-benefits in monetary and time terms, per capita and per type of user (low, medium and high income). This disaggregation allows defining a transparent and consistent set of indicators and identifying the social equity effects.

We have selected the MARS model (Metropolitan Activity Relocation Simulator) (Pfaffenbichler, Emberger & Shepherd 2008) because it fits quite well with the requirements of the case study and the complexity of the interaction among several transport modes and type of activities. The MARS model has been calibrated for the regional and metropolitan area of Madrid (Guzmán 2011, Guzmán, Di Ciommo & Hoz 2013, Guzmán, Hoz & Monzón 2014). The development of the first MARS dates back to more than 13 years ago, and it was partially funded by the European Union research projects (OPTIMA (May, Shepherd & Timms 2000), FATIMA (May, Timms 2000) and PROSPECTS (Minken et al. 2003)). To date, MARS models have been developed for many European cities (Edinburg, Helsinki, Leeds, Madrid, Oslo, Stockholm, Bari and

Vienna), some Asian cities (Chiang Mai and Ubon Ratchathani in Thailand, and Hanoi in Vietnam) and in Porto Alegre, Brazil. The first application of a MARS model in the United States has been recently developed for Washington D.C.

MARS-Madrid was developed to simulate the future development of the land-use and transportation over time. The model is able to support policy evaluation and scenario testing over short, medium and long-term horizons. It uses the concepts of CLD, which provide the basis to study the cause and effect among the variables of the transportation system and the land-use. The current version of MARS is implemented in Vensim, a System Dynamics programming environment based on the analysis of speed vs. O-D demand relationships, and includes speed-flow functions that simulate the current transport network. These functions are calibrated for Madrid Network with the VISUM® specialized transport modeling.

The MARS-Madrid model has been calibrated for the regional and metropolitan area of Madrid. The modal split for both commuting trips (home-work) and other trips (home-other) is calculated using the Madrid 2004 mobility survey. Other data inputs that were used in the project include:

- Constant travel time budget: 87 min.
- Average trips by worker: 2.04.
- Time value (commuting and other at prices 2004): 10.45 €/h and 5.70 €/h.

Whereas the MARS-Madrid model estimates the mobility patterns on the scenarios conditioned by exogenous variables and road charge policy, the optimization procedures seek the maximum welfare scenario that may be generated through the congestion charging. In general, the optimization of the welfare function considers the same discount rate for all agents included in the welfare function (Guzmán, Di Ciommo & Hoz 2013). In this paper different rates of discount, depending on the time preferences of each agent have been already integrated in the welfare function, showing that the use of more suitable discount rates for each social actor had an effect on the selection and definition of optimal strategy of congestion pricing. The usefulness of the measure of congestion toll declines more quickly over time. This result has been a key issue for understanding the relationship between transport system policies and social actors' benefits distribution in a metropolitan context (Guzmán, Di Ciommo & Hoz 2013).

In this context, social welfare function assembles the strategic variables that have been optimized. The objective function of MARS-Madrid model is the welfare function (WF), including the sum of agents' social benefits optimized throughout the complete period of time. Thus the WF measures the change in social welfare compared to a reference scenario: the change in consumer surplus, which includes either the monetary costs (or savings) and time savings for users. The variation of the operator benefits includes gains

linked to revenues from fares and charges. The change of government benefits includes fuel tax revenues, and investment savings related with road costs maintenance. Finally, the variation of benefits for the society related with the external costs includes reduction of accidents, greenhouse gas emissions and pollution costs (Guzmán, Hoz & Monzón 2014).

The congestion-pricing scheme assessment has the objective to identify as precisely as possible the distributional effects for different population groups of users, where we take their individual characteristics such as income, location, travel patterns and car ownership/use characteristics. The toll scheme is implemented only for passenger vehicles.

2.1 Social welfare estimation

The objective function identified with the social welfare function assembles the strategic variables that have been optimized. The objective function of the LUTI model is the welfare function (WF), including the sum of all social benefits optimized throughout the complete period of time (Guzmán, Di Ciommo & Hoz 2013).

Thus the WF showed in Equation (1) measures the change in social welfare compared to the reference scenario. This function is defined by the following elements: the change in consumer surplus (ΔCS_{ijm}), which includes either the monetary costs (or savings) and time savings for users, resulting through the implementation of toll ring policy. The variation of the operator benefits (ΔO_{ijm}) includes gains linked to revenues from fares and charges. The change of government benefits (ΔG_{ijm}) includes fuel tax revenues, and investment savings related with road costs maintenance. Finally, the variation of benefits for the society related with the external costs (ΔE_{ijm}) includes reduction of accidents, greenhouse gas emissions and pollution costs.

$$WF = \sum_{t=0}^n \sum_{ijm} \left[(1/(1+r_u)^t) \cdot \Delta CS_{ijm}(t) + (1/(1+r_o)^t) \cdot \Delta O_{ijm}(t) + (1/(1+r_g)^t) \cdot \Delta G_{ijm}(t) + (1/(1+r_e)^t) \cdot \Delta E_{ijm}(t) \right] \quad (1)$$

The final evaluation is expressed by net present value (NPV) over the different scenarios, and using different discount rates (r_u, r_o, r_g, r_e) according with the considered social agents (users income level, operators, government and society). The government and the society social discount rate in this paper will be the same. The variable t represent the period of time. The variable m is the transport mode. The i and j subscripts refer to origin and destination zones, respectively. The estimated emissions value and casualties avoided is shown in Guzmán, Di Ciommo and Hoz (2013).

2.2 Consumer surplus computation

The Equation (2) shows the change in consumer surplus. This equation measures the change in social welfare compared to the reference scenario. This function is defined by the change in consumer surplus, which includes either the monetary costs (or savings) and time savings for users, resulting through the implementation of congestion-pricing scheme.

$$\Delta CS = \sum_{t=0}^n \sum_{ijm} \sum_{lmh} [(1/(1+r_l)^t) \cdot \Delta CS_{ijm}^l(t) + (1/(1+r_m)^t) \cdot \Delta CS_{ijm}^m(t) + (1/(1+r_h)^t) \cdot \Delta CS_{ijm}^h(t)] \quad (2)$$

The final result is expressed by net present value (NPV) over the different scenarios, and using different discount rates (r_l , r_m , r_h) according with the considered income groups (low, medium and high).

The user-type is characterized by a commuting trip from one zone to another and has a travel generalized costs in terms of time and money according to the transport mode chosen. Then, the assessment of the proposed congestion-pricing scheme includes users travel costs from this individual change. We call this like the total consumer surplus change (ΔCS) for the individual through the ‘‘rule of a half’’. The consumer surplus from a change in travel times and/or travel costs should in general be calculated at the level of origin-destination pair (Guzmán, Di Ciommo & Hoz 2013).

$$\begin{aligned} \Delta CS_{ijm}^r(t) &\approx \frac{1}{2} \sum_t \sum_{ijm} \sum_{lmh} [T_{ijm}^0(t)^r + T_{ijm}^1(t)^r] \cdot [G_{ijm}^0(t)^r - G_{ijm}^1(t)^r] \\ &\approx \frac{1}{2} \sum_t \sum_{ijm} \sum_{lmh} [T_{ijm}^0(t)^r + T_{ijm}^1(t)^r] \cdot (C_{ijm}^1(t)^r + t_{ijm}^1(t)^r \cdot VOT_i - C_{ijm}^0(t)^r - t_{ijm}^0(t)^r \cdot VOT_i) \end{aligned} \quad (3)$$

Where T_{ijm}^k is the demand for trips between i and j by mode m , in the k scenario; G_{ijm}^k is travel generalized cost; C_{ijm}^k is total travel cost including charging and operation cost; t_{ijm}^k is the travel time; and VOT_i is the value of time. If we let 0 and 1 denote ‘‘before’’ and ‘‘after’’ the congestion-pricing scheme, we will calculate the difference between 0 and 1 scenarios. The superscript k is used to denote either the scenarios.

Consumer surplus (i.e., the difference between user utility and its cost) implied a higher consideration for the high income users because it increases with the income of users. In other words, the consumer surplus of high income households has a higher weight with respect of the low income people. In this work, the income differences of people are included in the user utility (r), to partially correct this possible distortion and a higher inter-temporal preferences rate is used for low income population group.

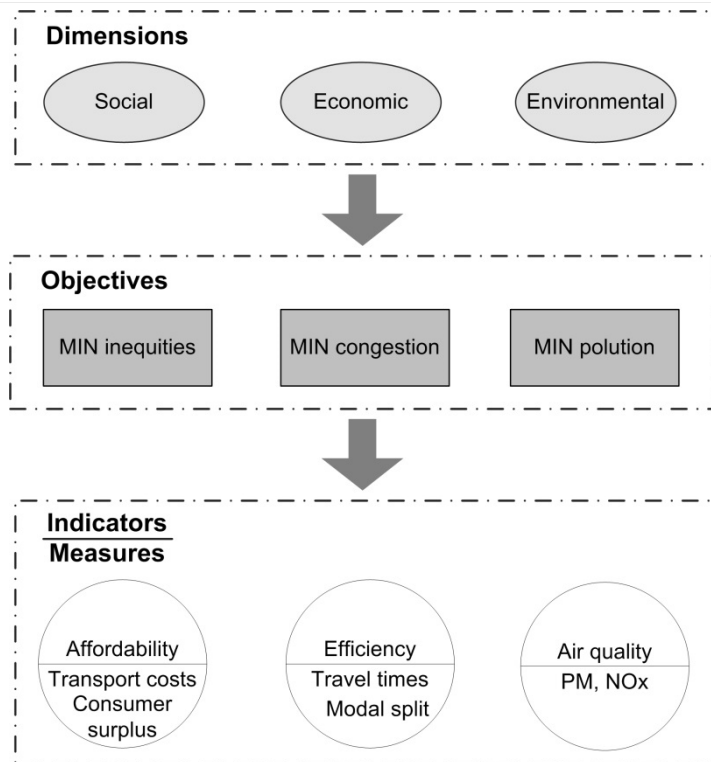


Fig 1 – Conceptual foundation of multidimensional indicators for a toll ring policy
Based in Miller

3. CASE STUDY

We propose a charging system which is defined by a cordon line: the area inside the ring road known as the M-30. The area of study has a high provision of public transportation, both in terms of coverage and service. In the base and alternative scenarios, projections were made for economic and population growth based on data from the Institute of Statistics in Madrid (Guzmán, Di Ciommo & Hoz 2013).

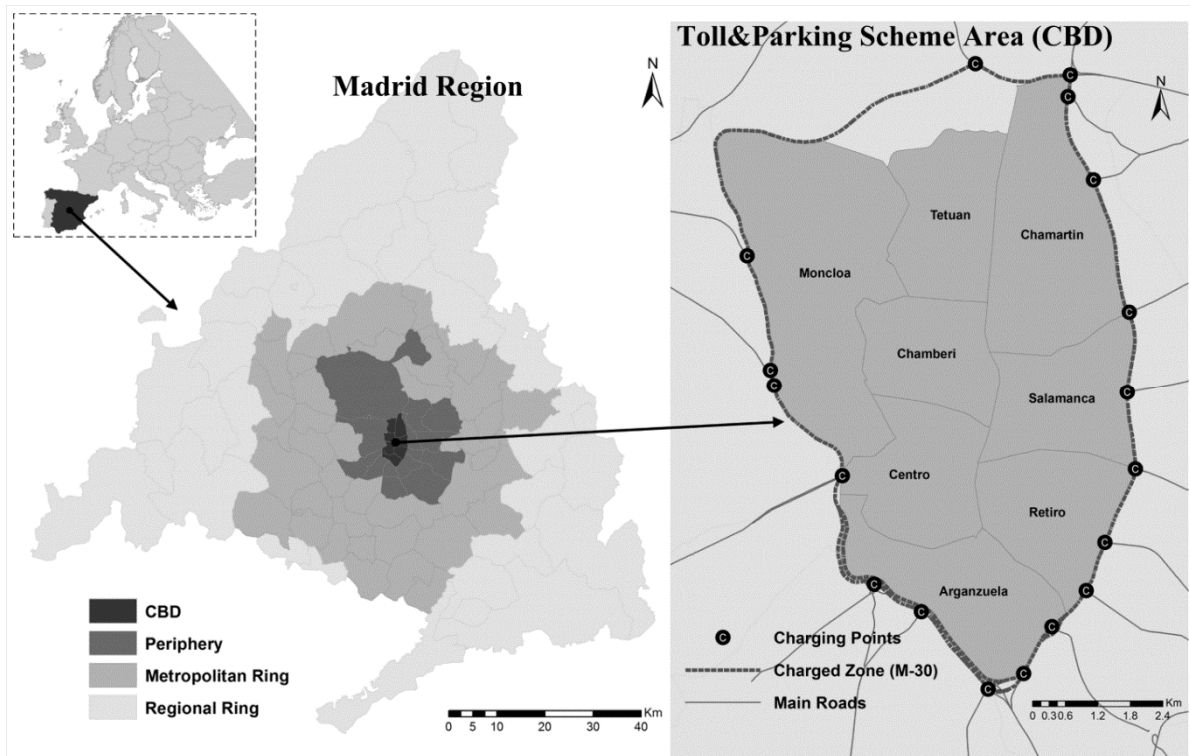


Fig. 2 – Modeled area and City center area

Low income (r_l) \leq 1.100 €/month per household

Medium income (r_m) between 1.100 and 3.100 €/month per household

High income (r_h) $>$ 3.100 €/month per household

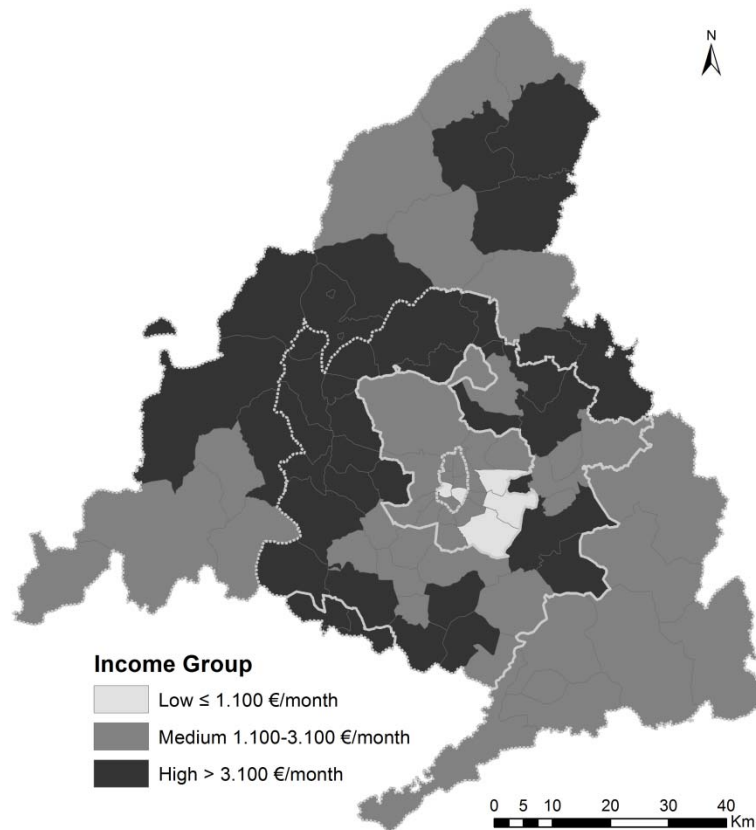


Fig. 3 – Madrid Region income levels by zone

Region of Madrid in 2004 was about 6.5 million inhabitants. According with this income distribution map, the low-income population is around 9% of the total. The medium-income people are 72% and high-income, 19%. The spatial income distribution shows that the highest income populations are localized in the northern part, while low income people in the southern part, with some interstitial zones.

3.1 Toll policy implementation

This method can be applied to optimize several types of transport policies; however in this case, the optimization process is proposed with an application of two variables: a toll-pricing policy profile for passenger vehicles (initial and final toll value) in Madrid city center. The introduction of the concept of “policy profiles” allows specifying policy instrument levels and optimized them for two points over time.

The introduction of the concept of “policy profiles” allows policy instrument levels to be specified and later optimized over the time. We define the main characteristics of a policy profile through $X(t_A)$ and $X(t_L)$ as the levels of the policy attributes respectively in the initial year t_A (the value of the policy when it is introduced) and in the short, medium and long-run (the final policy value after the intermediate adjustments). Similarly, t_A is the year in which the policy is introduced ($t_A = 2012$ in this study) and t_L identifies the end of the evaluation period on which the policy is evaluated ($t_L = 2017$). The t_s value is any intermediate evaluation point; we assume the toll increases linearly between the toll level

selected for t_A and t_L . The levels of instrument in intermediate years $X(t)$ are determined by interpolating a linear function, and the level is then assumed constant for any year after the t_L year as depicted in Figure 4.

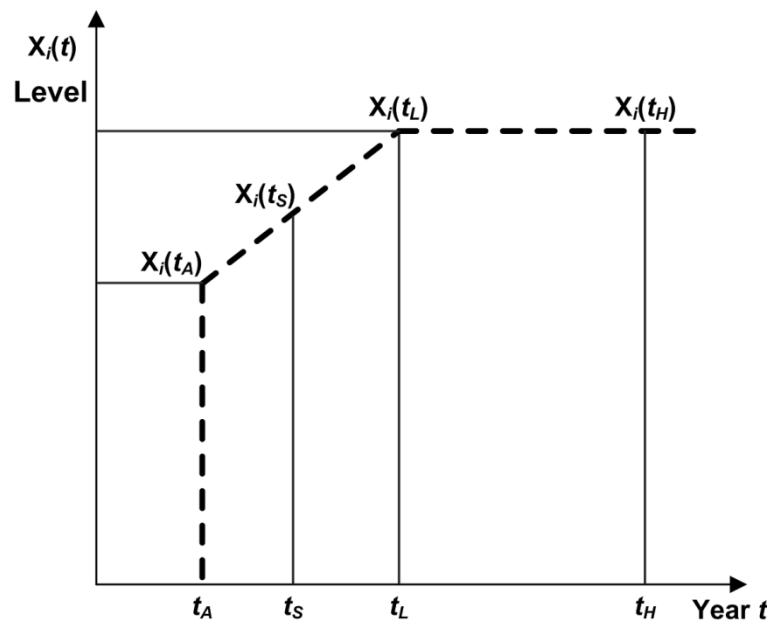


Fig. 4 – Instrument profile for continuous instruments

3.2 Scenario definition

In order to explore the social equity effects of a toll scheme values under different discount rates for each kind of user, an integrated framework was proposed seeking the maximum social welfare. These scenarios were compared with a baseline (labeled the do-nothing scenario), where no policy measures were assumed. Under a do-nothing scenario, the social welfare variation is assumed to be zero. Do-nothing scenario is needed to quantify the impact of transportation policies. In this case we propose three different scenarios:

1. **Scenario 1.** Estimate an optimal congestion toll values, using different rates of discount, depending on the time preferences of each agent (users, operators, government and society), as is shown and discussed in Guzmán, Di Ciommo and Hoz (2013). The optimum toll value obtained in alternative scenario behind the condition of the maximization of the NPV of the WF proposed will measure the social welfare compared to the reference scenario.
2. **Scenario 2.** Taking the optimal toll values results from Scenario 1, social welfare function is calculated again, but taking into account the income level groups and according to this, we used the discount rates shown in Figure 5. This will allow the discussion if consider equal or different user discount rates, influences on social welfare and whether this type of instrument is regressive or progressive.
3. **Scenario 3.** A toll ring policy is optimized using the user income level rates shown in Figure 5, so that it is possible to evaluate whether the inclusion of discount rates differentiated by type of user, can improve the WF performance with respect to equity.

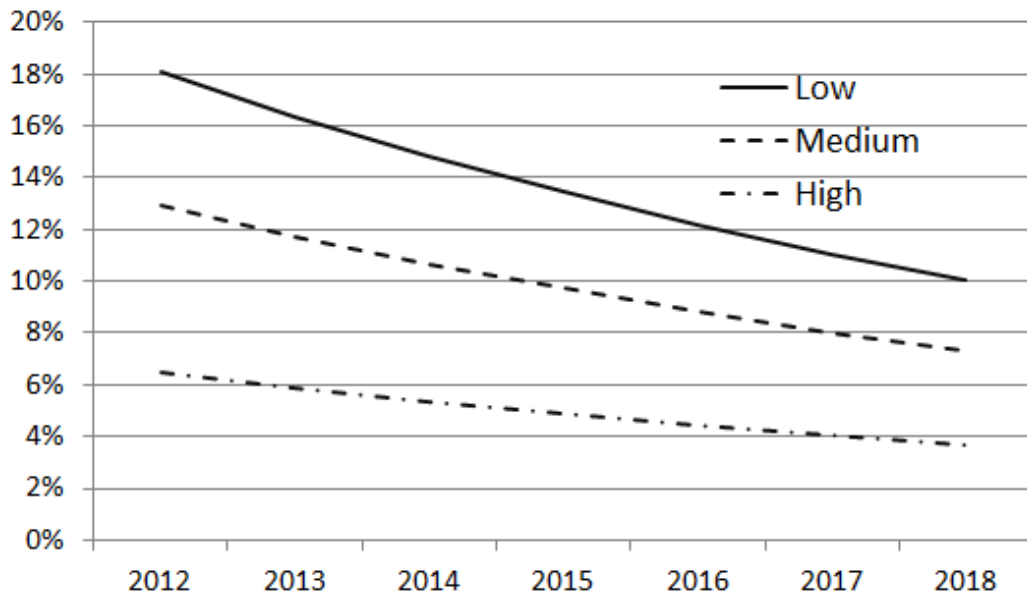


Fig. 5 – Discount rates by user type (low, medium and high income)

This paper aims to assess a new method by integrating different types of discount rate belonging to different social actors and income-level users in order to measure the real benefits of each actor in the short term (2012-2017). Table 1 show the scenarios used in this study.

	Scenarios		
	1	2	3
User discount rates			
Low	5.5%	Variable: Figure 5	Variable: Figure 5
Medium	5.5%		
High	5.5%		
Other social agents discount rates			
Operators	7.0%	7.0%	7.0%
Government	4.5%	4.5%	4.5%
Society	4.5%	4.5%	4.5%
Toll values	Optimum	Scenario 1	Optimum

Table 1 – Scenarios tested

A sensitivity analysis varying discount rates of social agents proves the consistency of the results of the simulation.

4. RESULTS

Increasing the travel cost by car to the city center (peak period), car traffic entering the cordon zone is reduced after the toll ring policy was implemented. But this reduction is according to the income level. According to the population distribution by income level (Figure 3), the toll policy affects mostly the medium-income population (68%) as is shown in Figure 6.

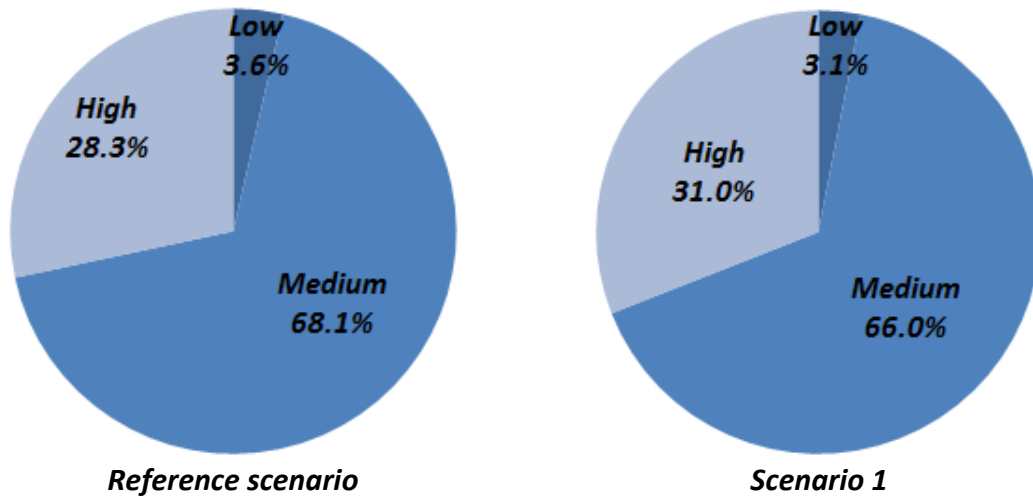


Fig 6 – Car use in trips to the city center by income level 2017

The car use increases with income level (Figure 7). As expected and compared with the reference scenario, the low-income people are the most affected group: the car trips reduction to the city center is between 3 and 26% according to scenario evaluated (value of toll fees). This means an absolute change in modal shift of 5.3% (Figure 8). Similarly, they are also the group who make the bigger modal shift from car to PT, once toll policy is implemented.

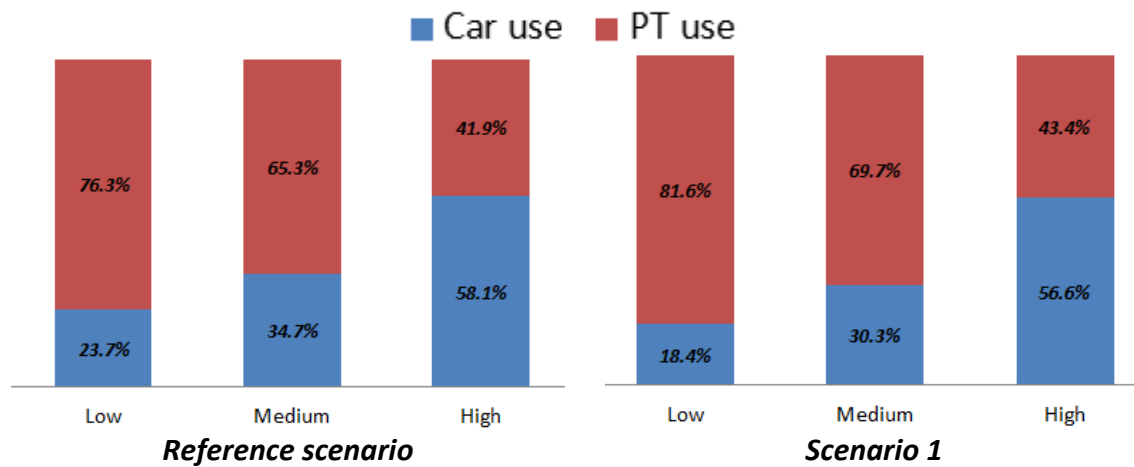


Fig 7 – Motorized modal split to the city center by income level 2017

This means that the low-income people lose 5.3 points in the car use share, which is a decrease in relative terms of 22.5%. Since low-income car trips to the city center are the minority (3.6%), this policy makes this proportion is even lower.

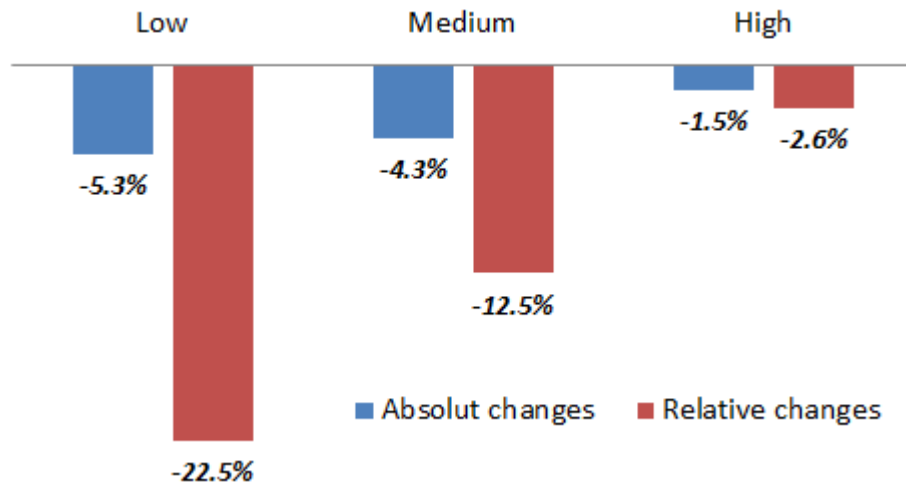


Fig 8 – Modal split changes before/after toll ring implementation by income level

Compared with the modal split of reference scenario, these results shows that Scenarios 1 and 2 present a bigger modal shift, but because the toll value is higher than Scenario 3 (see Table 2). However the modal split can show a first lead about the toll policy equity: the lower-income people are the most affected group. While a significant percentage of low and middle-income people change from car to public transport, the high-income group uses more their cars.

The social welfare function strategy shows a general positive social welfare enough to cover the generated costs. The time saving, is significant after the cordon toll implementation, however, the losing agent is the car user for whom the increased saving time is not enough to cover the monetary costs.

Analyzing the consumer surplus (user surplus) variations in all scenarios (Table 2), it is possible to conclude that in absolute *time saving* terms, the medium-income group is the most benefited, but at the same time, they are the ones who pay more (money savings). This social group is the one who contributes most to the variation of welfare. This occurs because they are the majority of the population of Madrid (72%). However, to study and compare which group is the most affected by the toll policy, it is necessary to analyze in relative terms, for example, variation of the costs/benefits per capita.

Scenario		1			2			3		
Social Welfare (M€)		74.85			79.04			80.98		
Toll value optimum	Year	t_A	t_L	t_A	t_L	t_A	t_L			
		2012	2017	2012	2017	2012	2017			
	Value (€)	$X(t_A)$	$X(t_L)$	$X(t_A)$	$X(t_L)$	$X(t_A)$	$X(t_L)$			
		1.5	2.5	1.5 *	2.5 *	2.3	0.2			
Consumer Surplus (M€)		<i>Low</i>	<i>Medium</i>	<i>High</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>
Time savings										
Car users		4.4	75.2	44.9	2.9	54.7	38.3	2.9	52.5	35.1
PT users		10.6	72.6	9.5	6.7	52.5	8.0	6.4	49.6	7.2

Money savings									
Car users	-16.2	-326.2	-142.0	-11.4	-254.6	-126.6	-10.3	-223.5	-106.8
PT users	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total benefit users	-1.3	-178.5	-87.6	-1.8	-147.4	-80.3	-1.0	-121.3	-64.5

Table 2 – Consumer surplus: alternative scenarios/reference scenario of the Madrid road charge scheme [NPV M€]

* Is not the optimum.

Given the amount of population by each income group, apparently we found that who lose the most, are those with higher incomes (Table 3).

The obtained results show that high income social group will benefit from the time savings. The time savings benefices mainly car users that can still use the cars after the toll implementation. These results are in line with the observed modal changes in modal split between the based scenario and scenario 1 Figure 6.

Scenario	1			2			3		
<i>Income group</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>
Time savings	24.6	31.6	41.5	15.8	22.9	35.4	15.3	21.9	32.4
Car users	7.2	16.1	34.3	4.8	11.7	29.3	4.7	11.3	26.8
PT users	17.43	15.5	7.2	11.0	11.2	6.1	10.6	10.6	5.6
Money savings	-26.7	-69.8	-108.5	-18.8	-54.5	-96.8	-17.0	-47.8	-81.6
Car users	-26.7	-69.8	-108.5	-18.8	-54.5	-96.8	-17.0	-47.8	-81.6
PT users	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total savings	-2.1	-38.2	-67.0	-3.0	-31.6	-61.4	-1.7	-26.0	-49.3

Table 3 – Costs/benefits per capita [NPV €]

But we get another issue: although the high-income people pay more for use their cars, the relative cost per household is not equal, because the income is different between each group, like presented in table

Indicator	Ratio	Scenario 1	Scenario 2
Time saving per capita	$X_{\text{high income}} / X_{\text{low income}}$	1.69	2.24
	$X_{\text{high income}} / X_{\text{medium income}}$	1.31	1.54
Cost savings per capita / income	$X_{\text{high income}} / X_{\text{low income}}$	0.61	0.55
	$X_{\text{high income}} / X_{\text{medium income}}$	0.62	0.53

Comparing the indicators in respect to income affordability measured in monetary terms, the advantages seems to be for low income user-type, while using the time saving measure

the advantages is lower for low-income than for higher income users. The results are respected when the optimization is done using the same discount rate or different discount rates for each kind of income user-type.

4. CONCLUSIONS

When calculating the money savings per capita relative to the average income-level, we find that the low-income population pay (additional transport costs) around 2% more than the medium-income population. These results seem quite fair. But, if we analyze the differences between low and high-income groups, the results show that the low-income people. Comparing the medium and high-income group, the results are similar: the medium-income people pay 61% more. This finding seems to reinforce the idea expressed in Guzmán, Di Ciommo and Hoz (2013), saying that the congestion pricing is a regressive policy measure. The practical implications of these results are relevant in terms of transport and equity analysis, showing how a congestions pricing could be a regressive measure for lower income people.

But what happens now if travelers have time preferences differentiated according to their income level? The Scenario 2 shows that when it is assumed that low-income people have a shorter vision (in money terms) than high-income people the low-income people has an higher discount rates as shown in Figure 5. In this case the ratio of time saving between is much higher higher and lower income people. The use of different discount rates stress the possible inequality of burdens and benefices produced by the congestion pricing.

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